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most interesting of valleys, Clark's Fork of the Yellowstone, still impressed with the many unsolved problems connected with the geology of the range. I at first visited the region in the expectation of finding a partially submerged range of Paleozoic and Mesozoic sediments. If ever such range existed, it had completely disappeared by profound subsidence. I then looked for the roots of some powerful dominating volcano which had been the source of the varying breccias, but this also I failed to discover. In its stead, if I interpret the facts correctly, I found penetrating the breccias the towering domes and pinnacles of granular and porphyritic rocks, which in some far-distant day, when denudation has removed a greater part of the overlying mass, may be found to form one connected body which erosion has already so far laid bare as to indicate that they all form a part of one broad complex of coarsely crystalline rock of early Tertiary age.

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*THE PHYSIOLOGICAL BASIS OF MENTAL LIFE.**

IF we demand a physiological process corresponding to every possible variation of the content of consciousness the structure of the brain seems far too uniform to furnish a sufficient manifoldness of functions. The mere number of elements cannot be decisive; if they are all functionally coordinated they can offer merely the basis for coordinated psychical functions. If we have psychical functions of different orders it would not help us even if we had some millions more of the uniform elements. It would be useless to deny that here exists a great difficulty for our present psychology; the only question is whether this difficulty really opposes the demands and supposi-

tions of psychophysical parallelism or whether it means that the usual theories of to-day are inadequate and must be improved. It seems to me that the latter is the case, and that hypotheses can be constructed by which all demands of psychology can be satisfied without the usual sacrifice of consistency. The situation is the following:

The whole scheme of the physiologists operates to-day in a manifoldness of two dimensions: they think the conscious phenomena as dependent upon brain excitements which can vary firstly with regard to their localities and secondly with regard to their quantitative amount. These two variations then correspond to the quality of the mental element and to its intensity. In the acoustical center, for instance, the different pitch of the tone sensations corresponds to locally different ganglion cells, the different intensities of the same tone sensation to the quantity of the excitement. Association fibers whose functions are not directly accompanied by conscious experiences connect these millions of psychophysical elementary centers in a way which is imagined on the model of the peripheral nerve. No serious attempt has been made to transcend this simple scheme. Certainly recent discussions have brought many propositions to replace the simple physiological association fiber which connects the psychophysical centers by more complicated systems—theories, for instance, in regard to the opening and closing of the connecting paths or in regard to special association centers or special mediating cell groups—but these and others stick to the old principle that the final psychophysical process corresponds to the strength and locality of a sensory stimulation or of its equivalent reproduction, whatever may have brought about and combined the excitements.

It is true that it has been sometimes suggested that the same ganglion cell may go

*Read before the joint meeting of the Psychological Association and the Physiological Society.

over also into qualitatively different states of excitement, and thus allow an unlimited manifoldness of new psychophysical variations. But it is clear that to accept such an hypothesis means to give up all the advantages of brain localization. The complicatedness of the cell would be in itself sufficient to give ground to the idea that its molecules may reach some millions of different local combinations, and if every new combination corresponds to a sensation all the tones and colors and smells and many other things may go on in one cell. But, then, it is, of course, our duty to explain those connections and successions of different states in one cell, and that would lead to thinking the cell itself as constructed with millions of paths just like a miniature brain; in short, all the difficulties would be transplanted into the unknown structure of the cell. If we, on the other hand, do not enter into such speculations the acceptance of qualitative changes in the cell would bring us to the same point as if we were satisfied to speak of qualitative changes of the brain in general. It would not solve the problem, but merely ignore it, and, therefore, such an additional hypothesis cannot have weight.

The only theory which brings in a really new factor is the theory of innervation feelings. This well-known theory claims that one special group of conscious facts, namely, the feelings of effort and impulse, are not sensations and, therefore, not parallel to the sensory excitements, but are activities of consciousness and parallel to the physiological innervation of a central motor path. At this point, of course, comes in at once the opposition of the philosophical claim that every psychical fact must be a content of consciousness, and made up of sensations, that is, of possible elements of idea, to become describable and explainable at all. The so-called active consciousness, the philosopher must hold, has nothing to do with an activity of the

consciousness itself, as consciousness means, from the psychological standpoint, only the kind of existence of psychical objects. It cannot do anything, it cannot have different degrees and functions, it only becomes conscious of its contents, and all variations are variations of the content, which must be analyzed without remainder into elements which are theoretically coördinated with the elements of ideas, that is, with the sensations, while consciousness is only the general condition for their existence. But also the empirical analysis and experiment of the practical psychologist are in this case in the greatest harmony with such philosophical claims and opposed to the innervation theory. The psychologist can show empirically that this so-called feeling of effort is merely a group of sensations like other sensations, reproduced joint and muscle sensations which precede the action and have the rôle of representing the impulse merely on account of the fact that their anticipation makes inhibitory associations still possible. It would thus from this point of view also be illogical to think the psychophysical basis of these sensations different in principle from that of other sensations. If the other sensations are accompaniments of sensory excitements in the brain the feelings of impulse cannot claim an exceptional position.

But are quality and intensity really the only differences between the given sensations? Can the whole manifoldness of the content of consciousness really be determined by variations in these two directions only? Certainly not; the sensations can vary even when quality and intensity remain constant. As an illustration we may think, for instance, of one variation which is clearly not to be compared with a change in kind and strength of the sensation; namely, the variation of vividness. Vividness is not identical with intensity; the vivid impression of a weak sound and the

unvivid impression of a strong sound are in no way interchangeable. If the ticking of the clock in my room becomes less and less vivid for me the more I become absorbed in my work, till it finally disappears, it cannot be compared with the experience which results when the clock to which I give my full attention is brought farther and farther away. The white impression, when it loses vividness, does not become gray and finally black, nor the large size small, nor the hot lukewarm. Vividness is a third dimension in the system of psychical elements, and the psychologist who postulates complete parallelism has the right to demand that the physiologist show the corresponding process. There are other sides of the sensation for which the same is true; they share with vividness the more subjective character of the variation, as, for instance, the feeling tone of the sensation or its pastness and presentness. Other variations bring such subjective factors into the complexes of sensations without a possibility of understanding them from the combination of different kinds only; for instance, the subjective shade of ideas we believe or the abstractedness of ideas in logical thoughts. In short, the sensations and their combinations show besides kind, strength and vividness still other variations which may best be called the values of the sensations and of their complexes. Is the typical theory of modern physiological psychology, which, as we have seen, operates merely with the local differences of the cells and the quantitative differences of their excitement, ever able to find physiological variations which correspond to the vividness and to the values of the sensations?

An examination without prejudice must necessarily deny this question. Here lies the deeper spring for the latent opposition which the psychophysiological claims find in modern psychology. Here are facts, the

opponents say, which find no physiological counterpart, and we must, therefore, acknowledge the existence of psychological processes which have nothing to do with the physiological machinery. The vividness, for instance, is fully explained if we accept the view that the brain determines the kind and strength of the sensation, while a physiologically independent subject turns the attention more or less to the sensation. The more this attention acts the more vivid the sensation; in a similar way the subjective acts would determine the feeling tone of the sensation by selection or rejection, and so on. While the usual theory reduces all to the mere association of locally separated excitements, such a theory thus emphasizes the view that the physiologically determined functions must be supplemented by an apperceiving subject which takes attitudes. We may call the one the association theory; the other the apperception theory. We have acknowledged that the association theory is insufficient to solve the whole problem, but it is hardly necessary to emphasize that the apperception theory seeks the solution from the start in a logically impossible direction, and is thus still more mistaken than the association theory.

The apperception theory, whatever its special label and make-up may be, does not see that the renunciation of a physiological basis for every psychical fact means resigning the causal explanation altogether, as psychical facts as such cannot be linked directly by causality, and that resigning the causal aspect means giving up the only point of view which comes in question for the psychologist. If those apperceptive functions are seriously conceived without physiological basis they represent a manifoldness which can be linked merely by the teleological categories of the practical life, and we sink back to the subjectifying view which controls the reality of life, but which

is in principle replaced by the objectifying view as soon as the experience of the subject is acknowledged as a series of psychological objects.

But does this bankruptcy of all varieties of apperception theories necessarily force us back to the association theory? I do not think so. The demand of the association theory that every psychosis should be accompanied by a neurosis cannot be given up, but this neurosis may be thought in a richer way than in the scheme of the associationists. It seems to me, indeed, that the physiological theory works to-day with an abstract scheme with which no observation agrees. We do not know of a centripetal stimulation which does not go over into centrifugal impulses. The studies on tonicity and actions of voluntary muscles, on the functions of glands and blood vessels, on tendon reflex centers, and so on, show how every psychophysical state discharges itself into centrifugal functions. And yet these perceivable peripheral effects are, of course, merely a small part of the centrifugal impulses which really start from the end stations of the sensory channel, as most of them probably produce only new dispositions in lower motor centers without going directly over into movement, and others may fade away in the unlimited division of the discharge in the ramification of the system. Those milliards of fibers are not merely the wires to pull a few hundred muscles; no, the centrifugal system represents certainly a most complex hierarchy of motor centers too, and the special final muscle impulse is merely the last outcome of a very complex cooperation of very many factors in the centrifugal system. Manifold as the incoming nerve currents must be, thus, also the possibilities of centrifugal discharge, and the dispositions in the nervous motor system determine the degrees in which the ganglion cells can transform the centripetal into centrifugal stimulation. It

is thus not only the foregoing sensory process, but in exactly the same degree also the special situation of the motor system, its openness and closedness, which governs the process in the center. Whether the special efferent channel is open or plugged implies absolutely different central-processes in spite of the same afferent stimulus.

Here we have, then, a new factor on the physiological side which is ignored in the usual scheme that makes the psychical facts dependent upon the sensory processes only and considers the centrifugal action of the brain as a later effect which begins when the psychophysical function is over. There is no central sensory process which is not the beginning of an action too, and this centrifugal part of the central process necessarily varies the accompanying psychical fact also. As here the action of the center becomes the essential factor in the psychophysical process, we may call this view an action theory as over against the association and apperception theories of the day. The action theory agrees, then, with the associationism in the postulate that there is no psychical variation without variation on the physiological side and with the apperceptionism in the conviction that the mere association of sensory brain processes is insufficient to play the counterpart to the subjective variation of the psychical facts as vividness and values of the sensations. It tries to combine the legitimate points in both views, and claims that every psychical sensation as element of the content of consciousness is the accompaniment of the physical process by which a centripetal stimulation becomes transformed into a centrifugal impulse.

This central process thus clearly depends upon four factors: firstly, upon the local situation of the sensory track; secondly, upon the quantitative amount of the incoming current; thirdly, upon the local situation of the outgoing discharge; and

fourthly, upon the quantitative amount of the discharge. The first two factors are, of course, determined by the incoming current, which can be replaced by an intracortical stimulation from an associated center, while the last two factors are determined by the dispositions of the centrifugal system. The association theory, which considers the first two factors alone, thinks them parallel to the kind and strength of the sensation. The action theory accepts this interpretation and adds that the two other factors determine the values and the vividness of the sensation—the values parallel to the local situation of the discharge, the vividness to the openness of the centrifugal channel, and thus to the intensity of the discharge.

If the centrifugal discharge is inhibited, the channel closed, then the sensory process goes on as before, but the impression is unvivid, unperceived, while it may become vivid later as soon as the hindrance of the discharge disappears. The inhibition of ideas which remains unexplainable to the associationists would then mean that a special path of discharge is closed, and thus the idea which needs that discharge for its vividness cannot come to existence; the hypnotizer's words, for instance, close such channels. Only discharges, actions, can be antagonistic and thus under mutual inhibition; ideas in themselves may be logically contradictory, but not psychologically, while one action makes the antagonistic action, indeed, impossible, and the inhibition of ideas results merely from the inhibition of discharges. If this view is correct it is clear that while we strictly deny the existence of special innervation sensations we can now say that every sensation without exception is physiologically an innervation sensation, as it must have reached some degree of vividness to exist psychologically at all.

With regard to the local situation of the motor discharge the manifoldness of pos-

sibilities is evident. The channels may be closed in one direction, but open in others; the actually resulting discharge must be the product of the situation in the whole centrifugal system, with its milliards of ramifications, and the same sensory stimulus may thus under a thousand different conditions produce a thousand different centrifugal waves, all, perhaps, with the same intensity. The vividness would then be always the same, and yet the difference of locality in the discharge must give new features to the psychical element. A few cases as illustrations must be sufficient. We may instance the shades of time-direction; the same idea may have the subjective character of past, present and future. It corresponds to three types of discharge: the discharge which does not include action on the object any more appears as past; that which produces action as present, and that which prepares the action as future. In this group belong also the feeling tones: the pleasurable shade of feeling based on the discharge towards the extensors; the unpleasant feelings based on the innervation of the flexors. Here belong the differences between mere perception and apperception, as in the one case the discharge is determined by the impression alone, in the other case by associations also. Here belong the characteristics of the abstract conception which may be represented by the same sensational qualities which would form a concrete idea and yet has a new subjective tone because the centrifugal discharge is for the concrete idea a specialized impulse, for the conception a general impulse which would suit all objects thought under the conception. Here belongs, also, the feeling of belief which characterizes the judgment; the judgment differs psychophysically from the mere idea in the fact that the ideas discharge themselves in a new tonicity, a new set of the lower motor centers, creating thus a new

disposition for later reactions. To be sure, many of these discharges lead finally to muscle contractions which bring with them centripetal sensations from the joints, the muscles, the tendons, and these muscle and joint sensations themselves then become a part in the idea, for instance, of time, of space, of feeling. But the new part only reinforces the general tone which is given in the general discharge, and gives to it only the exact detail which gets its character just through the blending of these sensations of completed reactions with the accompaniments of the central discharge.

A consistent psychology thus may start with the following principles: It considers all variations of mental life as variations of the content of consciousness, and this content as a complex object, including in this first presupposition a complicated transformation of the real inner life, a transformation by which the subjectifying view of real life is denied for the causal psychological system. Every content of consciousness is further considered as a complex of sensations, that is, of possible elements of perceptive ideas. Every sensation is considered as having a fourfold manifoldness, varying in kind, in strength, in vividness and in value. The physiological basis of every sensation, and thus of every psychical element, is the physical process by which a centripetal stimulation becomes transformed into a centrifugal impulse, the kind depending upon the locality of the centripetal channel, the strength upon the quantity of the stimulus, the value upon the locality of the centrifugal channel, and the vividness upon the quantity of the discharge.

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SOPHUS LIE.

ON the eighteenth of February, 1899, the greatest mathematician in the world, Sophus Lie, died at Christiania in Norway.

He was essentially a geometer, though applying his splendid powers of space creation to questions of analysis. From Lie comes the idea that every system of geometry is characterized by its group. In ordinary geometry a surface is a locus of points; in Lie's *Kugel-geometrie* it is the aggregate of spheres touching this surface. By a simple correlation of this sphere-geometry with Pluecker's line-geometry, Lie reached results as unexpected as elegant. The transition from this line-geometry to this sphere-geometry was an example of contact-transformations.

Now contact-transformations find application in the theory of partial differential equations, whereby this theory is vastly clarified. Old problems were settled as sweepingly as new problems were created and solved.

Again, with his *Theorie der Transformationsgruppen*, Lie changed the very face and fashion of modern mathematics.

A magnificent application of his theory of continuous groups is to the general problem of non-Euclidean geometry as formulated by Helmholtz. To this was awarded the great Lobachévski Prize. Not even this award could sufficiently emphasize the epoch-making importance of Lie's work in the evolution of geometry.

Moreover, the foundations of all philosophy are involved. To know the non-Euclidean geometry involves abandonment of the position that axioms as to their concrete content are necessities of the inner intuition; likewise abandonment of the position that axioms are derivable from experience alone.

Lie said that in the whole of modern mathematics the weightiest part is the theory of differential equations, and, true to this conviction, it has always been his aim to deepen and advance this theory. Now it may justly be maintained that in his theory of transformation groups Lie has